



Institute for Materials Science

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Institute for Materials Science Distinguished Lecture Series



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Karlsruhe, Germany

Entropy Landscape of Materials with Strong Electronic Correlations Near Quantum Criticality

Tuesday, January 26, 2016

3:00 - 4:00pm

MSL Auditorium (TA-03 - Bldg 1698 - Room A103)

Abstract: In a number of materials, a second-order phase transition can be driven to zero temperature by a non-thermal control parameter such as pressure, magnetic or electric field, or composition. The origin of this unusual effect often arises from competing interactions. An example is the competition between the Kondo effect leading to local singlet states and the RKKY interaction favoring long-range magnetic order. As the temperature T is lowered towards absolute zero in the vicinity of such a quantum critical point (QCP), quantum fluctuations become increasingly important. They lead to unconventional scaling behavior of thermodynamic and transport properties and an accumulation of entropy at very low T , thereby allowing new types of electronic excitations and new phases. The enhanced entropy S when approaching a quantum critical point (QCP) can be probed by measurements of the specific heat, and its dependence on pressure can be studied by volume thermal expansion.

Anisotropic systems allow elucidating the nature of a QCP by employing multiple tuning parameters associated with stress applied along different directions. This will be shown for the heavy-fermion metal $\text{CeCu}_6\text{-xAu}_x$ which presents a canonical example of a quantum critical system that can be tuned to a QCP (at $x = x_c \approx 0.1$) by composition or (for fixed $x > x_c$) by hydrostatic pressure or magnetic field [1]. Inelastic neutron scattering studies of the heavy-fermion compound $\text{CeCu}_6\text{-xAu}_x$ have provided evidence of strongly anisotropic quantum fluctuations [2]] with unusual energy/temperature scaling [3]. We have investigated the anisotropy of the thermal-expansion coefficients for $x = 0.1$. Here, the directionally dependent stress Grüneisen ratios constitute a direct measure of the presence and strength of thermodynamic singularities. We establish a procedure to identify the combination of stresses that aims directly at the QCP and accomplishes the steepest change of the entropy [4]. We thereby can identify the optimal way to approach the QCP and directly link it with the geometry of the underlying quantum critical fluctuations. This new approach to quantum criticality allows uncovering the scaling behavior of the associated singularities, and reveals a rich entropy landscape.

[1] H. v. Löhneysen, A. Rosch, M. Vojta, and P. Wölfle, Rev. Mod. Phys. 79, 1016 (2007) [2] O. Stockert, M. Enderle, and H. v. Löhneysen, Phys. Rev. Lett. 99, 237203 (2007) [3] A. Schröder, G. Aeppli, R. Coldea, M. Adams, O. Stockert, H. v. Löhneysen, E. Bucher, R. Ramazashvili, and P. Coleman, Nature 407, 351 (2000) [4] K. Grube, S. Zaum, O. Stockert, Q. Si, and H. v. Löhneysen (to be published)

Bio: Hilbert v. Löhneysen studied physics in Göttingen, Germany and obtained his PhD 1976 from the University of Cologne. After a postdoc position at the CNRS Grenoble, France, he went to RWTH Aachen University and obtained his habilitation degree in 1981. Since 1986 he has been a full professor at the Physics Institute of the University of Karlsruhe. In 2000 he accepted the additional task of director of the Institute for Solid State Physics at the National Research Center Karlsruhe. Since 2009 he has held these offices in the newly founded Karlsruhe Institute of Technology, the merger of University and Research Center. From 1995 to 2001 he was a member of the Senate and Main Grants Committee of Deutsche Forschungsgemeinschaft (DFG, German Science Foundation) and from 2006 to 2012 of the German Council of Science and Humanities. His research interests are in the field of strongly correlated electron systems, magnetism and superconductivity, with focus on quantum phase transitions, and in the field of electronic properties of metallic nanostructures. Hilbert von Löhneysen is a member of the Heidelberg Academy of Sciences and Humanities, the German Academy of Science and Technology (acatech), and the Hector Fellow Academy.

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